Light Emitting Diode

Thermal Design Guide for the Nichia NVSU119C (U375, U385, U395, U405) LEDs

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1. Overview

The light output of LEDs decreases due to the effect of heat generation. When LEDs are operated above the maximum LED junction temperature (T_{JMAX}), the reliability will drop significantly. In order to use the NVSU119C LED with high performance and high reliability, it is important to design the heat dissipation so that the junction temperature T_J does not exceed 125°C for the T_{JMAX} for U375 and U385 ranks and 130°C for the T_{JMAX} for U395 and U405 ranks.
This application note covers the effect on the T_J when a board with one LED is driven with two different heat dissipation configurations and the T_J of a board with multiple LEDs. This information can be used as a reference for thermal design.

2. T_J Measurement Method

The following equation can be used to calculate the T_J.

$T_J = T_S + R_{\theta JS} \times W$

T_J : LED Junction Temperature (°C)
T_S : Soldering Temperature (°C)
$R_{\theta JS}$: Thermal Resistance from Junction to T_S Measurement Point (°C/W)
W : Input Power (W) = I_F(A)×V_F(V)

The specifications of the NVSU119C are as follows:

Symbol	Condition	NVSU119C							
		U375		U385		U395		U405	
		Typ	Max	Typ	Max	Typ	Max	Typ	Max
$R_{\theta JS}$ (°C/W)	-	3.4	3.8	2.6	3.1	2.6	3.1	2.4	3.1
V_F (V)	I_F=700mA	3.4	-	3.35	-	3.3	-	3.1	-

Absolute Maximum Ratings (T_S=25°C):

I_{FMAX} (mA)	1400
I_{FPMAX} (mA)	2000
T_{opr} (°C)	-10～85
T_{JMAX} (°C)	125(U375, U385), 130(U395, U405)

I_F : Forward Current (mA)
I_{FP} : Pulse Forward Current (mA)
I_{FP} conditions : pulse width ≤10ms and duty cycle ≤10%
T_{opr} : Operating Temperature (°C)

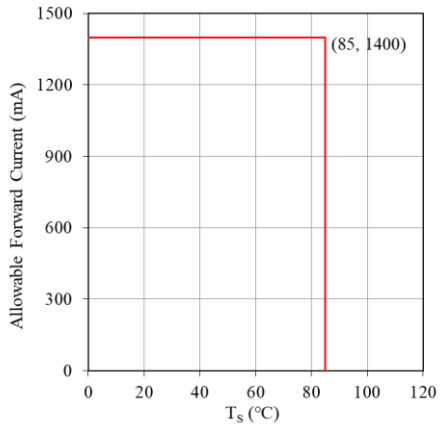


Figure 1. T_S vs Allowable Forward Current

3. T_S Measurement Point

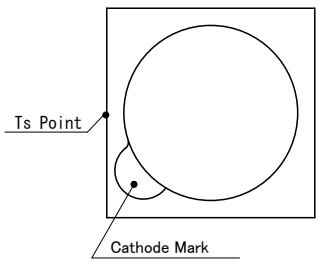


Figure 2. T_S Measurement point

4. Heat Dissipation Configuration and T_J Measurement Results

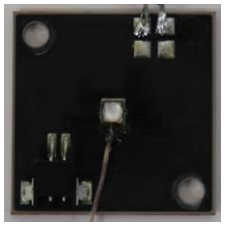
The T_J was confirmed when one LED was mounted on the board and it was driven with two different heat dissipation configurations.

Heat dissipation configuration 4-1, One LED on the board + Heatsink A

The specification of the board is as follows:

Thickness(mm)			Outline dimensions (mm)
Copper foil	Insulation layer	Copper base	
0.105	0.120	1.5	30 × 30

The thermal conductivity of the copper foil and copper base is 390W/m·K and that of the insulation layer is 4.5W/m·K.



Picture 1. Board appearance

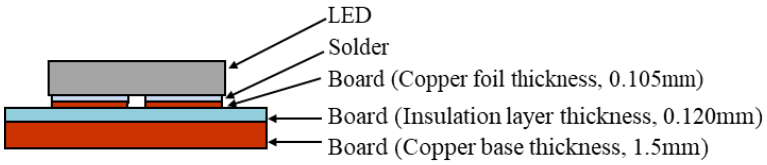


Figure 3. Structure of the board + LED

The specification of heatsink A is as follows:

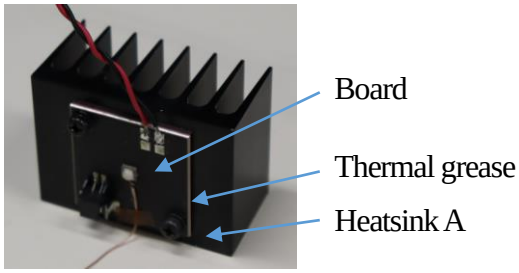
Heatsink A			Fin			Thermal resistance (°C/W)
Material	Size (mm)	Thickness of the base Material (mm)	Number of fins	Size (mm)	Arrangement	
Al	50 × 38 × t25	5	8	1 × 38	8 × 1	5.70

Thermal conductivity of thermal grease is 5.3W/m·K.

The results of the evaluation with heatsink A are shown below:

T_A (°C)	Part number	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (°C)	T_J (°C)
25	NVSU119C	U375	0.7	3.4	2.4	40	49
			1.4	3.5	4.9	55	74
		U385	0.7	3.3	2.3	39	46
			1.4	3.4	4.8	52	67
		U395	0.7	3.3	2.3	39	46
			1.4	3.4	4.8	53	68
		U405	0.7	3.1	2.2	37	44
			1.4	3.2	4.5	49	63

With heat dissipation configuration 4-1 using the U375 rank, there was enough margin to not exceed the T_{JMAX} even when 1.4A was applied. The shorter the wavelength, the tighter the heat dissipation, the results for the other wavelengths showed even greater margins for the heat dissipation.
Nichia performed another evaluation where the size of the heatsink was increased.



Picture 2. Evaluated light source 4-1

Heat dissipation configuration 4-2, One LED on the board + Heatsink B

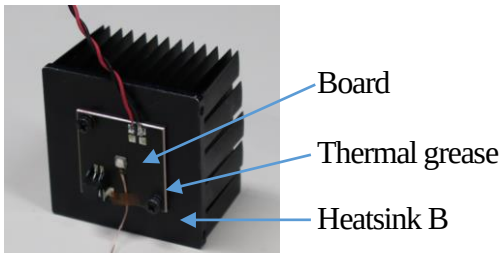
The specification of heatsink B is as follows:

Heatsink B			Fin			Thermal resistance (°C/W)
Material	Size (mm)	Thickness of the base Material (mm)	Number of fins	Size (mm)	Arrangement	
Al	53 × 53 × t35	4	64	0.8 × 9	13 × 5	4.25

Thermal conductivity of thermal grease is 5.3W/m·K.

The results of the evaluation with heatsink B are shown below:

T_A (°C)	Part number	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (°C)	T_J (°C)
25	NVSU119C	U375	0.7	3.4	2.4	38	47
			1.4	3.5	4.9	51	70
		U385	0.7	3.3	2.3	36	43
			1.4	3.4	4.8	48	63
		U395	0.7	3.3	2.3	36	43
			1.4	3.4	4.8	47	62
		U405	0.7	3.1	2.2	34	41
			1.4	3.2	4.5	45	59



Picture 3. Evaluated light source 4-2

By increasing the size of the heatsink from A to B, the heat dissipation performance was improved and the T_J was further lowered.

5. Design Considerations

The performance of naturally air-cooled heatsinks varies depending on the orientation of the fins of the heatsink. Since the T_S will increase when warm air accumulates, it is important that the air movement is not obstructed. At Nichia, the fins are placed to face vertically to allow warm air to escape from the top (See Figure 4).
When designing the system, pay attention to the orientation of the fins when installing the heatsink.

Picture 4.
Fins facing vertical
(Nichia uses this orientation)

Picture 5.
Fins facing down
(This orientation obstructs the air flow)

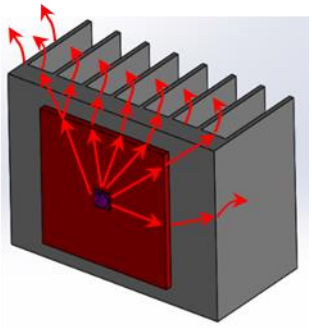


Figure 4.
Image of the heat path when fins are facing vertical

6. Applications

When multiple LEDs are mounted, the heat dissipation will be more severe. For reference, the T_J of a board with 144 NVSU119C(U385) LEDs cooled by a heatsink with a fan is shown below. This information can be used as a reference for thermal design.

Heat dissipation configuration 6-1, 144 LEDs on the board + Heatsink with fan (heatsink C with fan attached)

The specification of the board is as follows:

Thickness(mm)			Outline dimensions (mm)	LED mounting pitch (mm)
Copper foil	Insulation layer	Copper base		
0.035	0.120	1.5	25.3 × 45	4.2

The thermal conductivity of the copper foil and copper base is 390W/m·K and that of the insulation layer is 11.1W/m·K.

Picture 6. Board appearance

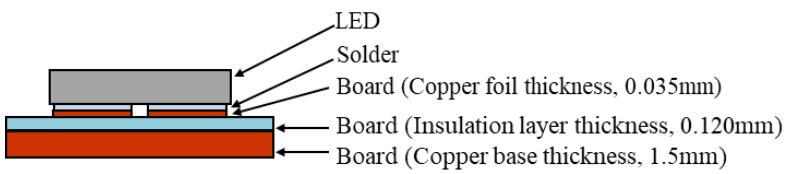


Figure 5. Structure of the board + LED

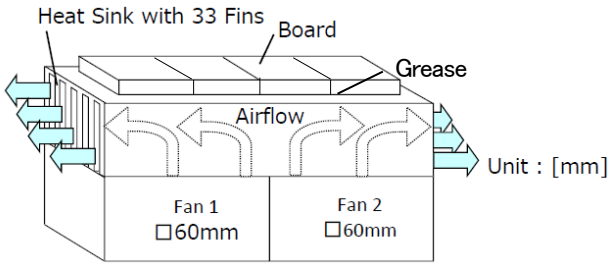


Figure 6. Evaluated light source 6-1

Picture 7. Appearance (Surface)

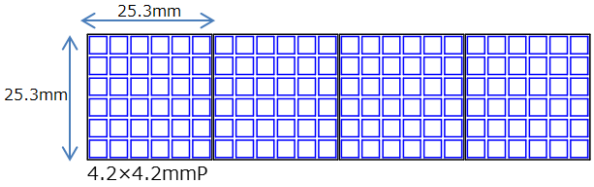


Figure 7. Light source
(6 x 6pcs. LEDs on one board x 4 boards)

Picture 8. Appearance (Back)

The specification of heatsink C is as follows:

Heatsink C			Fin		
Material	Size (mm)	Thickness of the base Material (mm)	Number of fins	Size (mm)	Arrangement
Al	150 × 63.5 × t52	15	33	150 × 0.7	1 × 33

The specification of the fan is as follows:

Fan		
Size (mm)	Volume flow (m^3/min)	Static pressure (Pa)
60 × 60 × t38	2.15	617

The results of the evaluation with heatsink C are shown below:

T_A (℃)	Part number	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (℃)	T_J (℃)
25	NVSU119C	U385	0.5	2.3	1.2	45	49
			0.7	2.5	1.8	52	57
			1.0	2.9	2.9	64	73

With heat dissipation configuration 6-1, there was enough margin to not exceed the T_{JMAX} even when 1.0A was applied.

7. Summary

On a board with one LED, there was sufficient margin to stay under the T_{JMAX}, even with an air-cooling heat dissipation configuration using only a heatsink. Additionally, a larger heatsink size resulted in an even lower T_J.
When multiple LEDs are mounted with a high density, forced air cooling with a heatsink and a fan was sufficient to cool the LEDs. When high-density mounting using multiple LEDs, heat interference occurs between adjacent LEDs, resulting in poor heat dissipation. Make sure that the pitch width is sufficient, increase the heatsink size, or attach a fan to the heatsink, etc. and check that it is sufficiently cooled before use.

The absolute maximum ratings for the NVSU119C LED per the Nichia specification:

I_F=1.4A, T_{JMAX}=125°C(U375, U385), 130°C(U395, U405)

Nichia will not guarantee the LEDs if used above these ratings.

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